Early Journal Content on JSTOR, Free to Anyone in the World

This article is one of nearly 500,000 scholarly works digitized and made freely available to everyone in the world by JSTOR.

Known as the Early Journal Content, this set of works include research articles, news, letters, and other writings published in more than 200 of the oldest leading academic journals. The works date from the mid-seventeenth to the early twentieth centuries.

We encourage people to read and share the Early Journal Content openly and to tell others that this resource exists. People may post this content online or redistribute in any way for non-commercial purposes.

Read more about Early Journal Content at http://about.jstor.org/participate-jstor/individuals/early-journal-content.

JSTOR is a digital library of academic journals, books, and primary source objects. JSTOR helps people discover, use, and build upon a wide range of content through a powerful research and teaching platform, and preserves this content for future generations. JSTOR is part of ITHAKA, a not-for-profit organization that also includes Ithaka S+R and Portico. For more information about JSTOR, please contact support@jstor.org.

FORECASTING THE CROPS OF THE DAKOTAS

THE proofs of the new propositions that are offered in this paper require the use of forbidding algebraical formulae and irksome statistical tables; but the propositions themselves are not unimportant, and, in order to invite consideration, they are presented free from technicalities in a preliminary survey.

A Summary of Conclusions

(1) About half a century ago, when American economic life was preponderantly agricultural, our federal government instituted a crop-reporting service that has been of immense practical value to growers, manufacturers and consumers. As far as I am aware, it was the pioneer governmental attempt to describe the crops during the growing season and to forecast from the condition of the growing crops the probable ultimate yield. As the country has grown in population and expanded and diversified its crop area, the crop-reporting service has been correspondingly extended and improved and has now become the exclusive work of one of the most important bureaus of the Department of Agriculture. The working ideal of the service is to achieve a forecast of the crop yield by combining the direct observations of practical men with the more refined inquiries of technical experts. The direct observations of farmer correspondents familiar with local conditions and prevailing crops are checked and supplemented by state and federal experts, and the resulting data are scrutinized, tabulated and analyzed in the central office at Washington.

The purport of the multitudinous separate reports, tabulations and calculations is kept secret until the moment of making the general announcements, which are given to the public in the shape of monthly forecasts of the crops during their respective growth seasons.

In order that the information in these reports may be made available simultaneously throughout the entire United States, they are handed at an announced hour on report days, to all applicants and to the Western Union Telegraph Company and the Postal Cable Company, who have branch offices in the Department of Agriculture, for transmission to the Exchanges and to the press. These companies have reserved their lines at the designated time, and forward immediately the figures of most interest. A mimeograph or multigraph statement, also containing such estimates of conditions or actual production, together with the corresponding estimates of former years for comparative purposes, is prepared and sent immediately to Exchanges, newspaper publications, and individuals. The same day printed cards containing the essential facts concerning the most important crops of the report are mailed to the 77,000 post offices throughout the United States for public display.[1]

The commodity markets are in a state of nervous expectancy as the time approaches for the official forecasts, because great values are at stake. It has been estimated that in case of the cotton crop alone an error in the forecasts which should lead to a depression of one cent a pound in the price of cotton-lint would —assuming a crop equal to that of 1914—entail a loss of eighty million dollars to the farmers. The vast values at stake and the dangers when no official estimate is available of the manipulation of the markets in the interest of speculators are held to justify the large recurrent annual cost of the employment of the numerous correspondents, clerks and experts.

The business of economic science, as distinguished from economic practice, is to discover the routine in economic affairs. It seeks to separate out the elements of the routine, to ascertain their interrelations and to use the knowledge of their connections to anticipate experience by forecasting from known changes the probabilities of correlated changes. What light can economic science throw upon the problem of forecasting the yield of the crops? The problem is fundamental, because the alternating bounty and niggardliness of nature initiate changes that are reflected throughout the entire economic organism.

---

[1] *Government Crop Reports: Their Value, Scope, and Preparation*, Circular 17, Bureau of Statistics, U. S. Department of Agriculture, Washington, 1908. A more ample description of the character and aim of the crop-reporting service is given in my Forecasting the Yield and the Price of Cotton, pp. 52–58.

In the essay on *Forecasting the Yield and the Price of Cotton* I have shown from an investigation of cotton production in Texas, Georgia, Alabama and South Carolina—which are the four leading cotton states and which, together, produce sixty-five per cent of the entire cotton crop—that, in seventeen out of twenty cases, it is possible to forecast the yield more accurately from the accumulated weather than the government officials succeed in forecasting it from the data supplied by the direct observation of their agents. Indeed, in all the states except Texas—which is an exception probably because of the heterogeneous conditions that are due to its enormous size—it is possible to forecast the ultimate yield of cotton from the accumulated effects of the weather, for each month of the growth season, with as great a degree of accuracy as the government reports issued *two months later*. That is to say, for all of the states except Texas the forecasts from the accumulated weather at the end, respectively, of May, June and July are about as good as can be obtained by the official method *two months later*, at the end, respectively, of July, August and September.

In the present article the inquiry is shifted to an area remote from the Cotton Belt and is concerned with the leading cereals of North Dakota. In 1916, among the states of the United States, North Dakota ranked first in the production of spring wheat, second in the production of barley and seventh in the production of oats; and to these three crops, in 1918, seventy per cent of its crop area was devoted. By its importance as a cereal-producing state and its representativeness of conditions in a leading grain region, North Dakota supplies an informing instance in which to make a further test of the relative accuracy in the forecasting of crops from the weather and from the direct observation of crop conditions.

According to a Bulletin[1] of the United States Department of Agriculture, the average dates for planting in North Dakota are, for wheat, April 19 to May 12; for oats, April 26 to May 20; and for barley, May 12 to May 28. The average dates for harvesting are, for wheat, August 10 to August 20; for oats, August 8 to August 15; and for barley, August 6 to August 13. In the course of the growth season of these crops the federal crop-reporting bureau issues forecasts on June 1, July 1 and August 1. As there are three of these reports for each crop, and there are three leading crops, it is possible in nine cases to compare the accuracy of the government forecasts with the accuracy of the forecasts from the weather. In the following pages the detailed comparison is given, and it is found that in eight out of the nine cases the forecasts from the weather are decidedly more accurate than the forecasts made by official experts from the direct observations of the growing crops.

---

[1] Bulletin No. 757. *Farm Practices in Grain Farming in North Dakota*, by C. M. Hennis and Rex E. Willard, 1919, p. 25.

"Hardheaded practical business men" have for decades gained and lost millions as a result of the government crop-reports. These reports have been composed by official experts with the assistance of a personnel that would make a small army and at a cost that would finance a score of colleges. But whether the forecasts referred to the fleecy yield of the malarial lowlands of the Cotton Belt or to the cereal crops of the wind-swept, sun-baked plains of Dakota, a properly equipped economist, without leaving his study, could have reached more accurate predictions from the simple data published by the Weather Bureau.

(2) With the possibility firmly established of predicting the yield of the crops from the accumulated changes of the weather, one is led to inquire whether the changes themselves are not subject to law. A tentative suggestion of regularity in the weather of North Dakota and South Dakota is offered in the ensuing pages.

A detailed examination of the dependence in the yield of wheat, oats and barley upon the rainfall and temperature during their growth seasons revealed that one of the most important elements affecting the quantity of the yield in North Dakota is, in case of all three crops, the rainfall of May and June. Because of the critical importance of the precipitation of May and June, for all of the crops, it seemed desirable to begin the quest of periodicities with an analysis of the record of rainfall in these two months.

In the treatment of the problem of forecasting the crop yield from the weather, the investigation was confined to North Dakota in order to limit the amount of necessary statistical computation. But in the inquiry as to the periodicity of the May and June rainfall, the data of both North Dakota and South Dakota, from 1882 to 1918, were analyzed by technical methods to ascertain whether there are cycles between the limits of three and twelve years. It was found that if there are cycles between these limits their most probable lengths are approximately eight and eleven years. Of these two cycles the one of eight years has the greater amplitude. Its dates of maximum rainfall were, approximately, 1882, 1890, 1898, 1906, 1914. The dates of maximum rainfall for the eleven-year cycles were, approximately, 1882, 1893, 1904, 1915. If the two curves are combined into a compound cycle of eight years and eleven years, the maxima of the compound cycle will still be, approximately, at 1882, 1890, 1898, 1906, 1914.

The dates of minimum rainfall in the compound cycle bring to light facts of very great interest. It is common knowledge that the semi-arid region of the United States begins to the west of the one-hundreth meridian, and, as it happens, this meridian divides nearly in two both North Dakota and South Dakota. Both states have a small annual rainfall, and as the average precipitation does not greatly exceed the minimum necessary for vegetation, the dates of minimum rainfall indicated by the compound cycle of eight and eleven years in the critical months of May and June should be times of partial crop failures. The facts bear out this inference. If a cycle of eight years is fitted to an index number of the yield in the Dakotas of the three crops, wheat, oats and barley, the curve of yield is practically congruent with the eight-year cycle in the rainfall of May and June; and, similarly, the eleven-year cycle of yield is practically congruent with the eleven-year cycle in the rainfall of the two critical months. Furthermore, if a compound cycle of eight and eleven years is fitted to the index number of the yield of the three crops, the compound cycle shows a general correspondence with the compound cycle of rainfall; and the dates of minimum rainfall are, approximately, the dates of the observed partial crop failures.

(3) We have seen (a) that the yield of the crops may be predicted from the accumulated changes in the weather; (b) that a most important weather factor, the rainfall of the critical growth season of the crops, tends in the Dakotas to follow a compound cycle of eight and eleven years; (c) that the leading crops of the Dakotas, wheat, oats and barley, tend to follow the same constituent cycles. Are there similar normalities in the crop yield of other parts of the United States?

In the same manner in which the rainfall data for the Dakotas were technically analyzed to ascertain the existence or non-existence of cycles, the data for the three crops, wheat, oats and barley, were analyzed for the whole of the United States. The crude figures indicating the yield of the crops are notoriously inexact, but, nevertheless, the analysis of the data for the United States revealed that if there are crop cycles between three and twelve years we may say they are approximately four, eight and eleven years in length. If these three cycles are compared with the results already established for the Dakotas, we find that in case of the eight-year cycle the maxima for the three crops of the United States, for the three crops of the Dakotas and for the May and June rainfall in the Dakotas are, approximately, at 1882, 1890, 1898, 1906, 1914, and that the four-year cycle produces, in all cases, secondary maxima midway between these dates. The eleven-year cycle in the three crops of the United States, in the three crops of the Dakotas and in the rainfall of the Dakotas are likewise practically congruent.

(4) Independent and separate analyses of data with a view to uncovering periodicities have been made in earlier studies with regard to (a) the annual rainfall in the Ohio Valley; (b) cotton in the United States; (c) wheat, oats and barley in the United Kingdom; (d) wheat, oats and barley in France. These separate and independent studies have disclosed (i) that if there

are cycles between three and twelve years, two of the cycles are, approximately, of four and eight years in length; and (ii) that if the compound cycles of eight and four years are computed independently for these groups of data, the cycles reveal in all cases, major maxima at, approximately, 1882, 1890, 1898, 1906, 1914, with minor maxima approximately midway between these years.

These results taken together with the independent findings of the present paper enable us to conclude that the compound cycles of eight and four years for the May and June rainfall in the Dakotas, the annual rainfall in the Ohio Valley, the yield of cotton in the United States, the yield of wheat, oats and barley in the Dakotas, in the United States, in the United Kingdom and in France are, as far as concerns the dates of their maxima and minima, practically synchronous.

The Degree of Accuracy in the Government Forecasts

We come now to the technical part of our inquiry.

To understand the official method of forecasting the yield of the crops, one must have clearly in mind the technical meaning of the terms *normal*, *condition* and *indicated yield per acre*.

The Normal. The official description of the term normal runs as follows:

> To begin with, a normal condition is *not* an *average* condition, but a condition *above* the average, giving promise of *more than an average crop*. Furthermore, a normal condition does *not* indicate a *perfect* crop, or a crop that is or promises to be the very largest in quantity and the very best in quality that the region reported upon may be considered capable of producing. The normal indicates something *less* than this, and thus comes between the average and the possible maximum, being greater than the former and less than the latter. The normal may be described as a condition of perfect healthfulness, unimpaired by drought, hail, insects, or other injurious agency, and with such growth and development as may reasonably be looked for under these favorable conditions.[1]

---

[1] *Crop Reporter*, May, 1899, p. 3. *Cf.* Circular 17 of the Bureau of Statistics of the Department of Agriculture, 1908, pp. 12–13.

Condition. The agents and correspondents of the Department of Agriculture are instructed to estimate the promise or condition of the growing crop as a percentage of the normal for the crop. They are asked to represent the normal by 100 and to express the current condition of the crop arithmetically as compared with the normal of 100 per cent. The correspondents are advised that they

> . . . will usually find it an advantage to have a definite idea of what yield per acre would constitute a full normal crop in their respective districts; that is, how many bushels, pounds, or tons per acre of a particular crop would be produced in a season that was distinctly but not exceptionally favorable. In a region where 30 bushels of corn may be taken as the normal, a condition of 90 would give a prospect of a crop of 27 bushels, and 80, a crop of 24 bushels.[1]

Indicated yield per acre. From the figures describing the condition of the crops, which are supplied by the agents and correspondents of the Department of Agriculture, the Crop-Reporting Board computes the indicated yield per acre for the several crops. An official description has been given of the method used in making the forecast.

> It is assumed, in the first place, that average conditions at any time are indicative of average yields per acre; that conditions above an average at any time are indicative of yields above the average; and conditions below the average at any time are indicative of yields below the average. If at any time the condition of a growing crop is 5 per cent above the average condition for such time, it is assumed that the yield is more likely to be 5 per cent above the average yield than any other amount. If the condition at any time is 10 per cent below the average for such time, it is assumed that the yield is more likely to be 10 per cent below the average than any other amount. . . . The process in the interpretation may be explained by an example. The condition of corn on July 1, 1911 was 80.1 per cent of a normal condition; in the last 5 years, the condition has averaged 85 per cent of a normal condition; thus the condition on July 1 is 5.8 per cent below the average condition (80.1 being 94.2 per cent of 85), and suggests a yield of 5.8 per cent below the average. In the last 5 years the yield

---

[1] *Crop Reporter*, May, 1899, p. 3.

averaged about 27.1 bushels; 94.2 per cent of 27.1 bushels (94.2 x 27.1) is nearly 25.5 bushels; therefore conditions are said to indicate a yield of 25.5 bushels.[1]

We propose to test the accuracy of the official method of forecasting when the method is applied to the crops of North Dakota.

As we have just seen, the method of the Crop-Reporting Board in making the forecast of the yield per acre of a crop is to assume that the ratio of the yield per acre for any given year to the mean yield per acre for the preceding five years is equal to the ratio of the condition of the crop for a given month to the mean condition for the given month during the preceding five years. The method becomes clearer when it is expressed in symbols: Let Y equal the prospective yield per acre of the crop for the current year; $\bar{Y}_5$ equal the mean yield per acre of the crop for the preceding five years; C equal the condition of the crop for the current month; $\bar{C}_5$ equal the mean condition for the same month during the preceding five years. Then, according to the assumption of the Crop-Reporting Board, $Y/\bar{Y}_5 = C/\bar{C}_5$. We shall call $Y/\bar{Y}_5$, the yield ratio; and $C/\bar{C}_5$, the condition ratio.

In Table I we have the record, for a quarter of a century, of the actual yield per acre of oats, and the yield as predicted, according to the method of the Crop-Reporting Board, from the condition of the crop on the first of August. The column marked $C/\bar{C}_5$ gives the ratio of the condition of the crop, at the first of August of any given year, to the mean condition of the crop, at the first of August, during the preceding five years. According to the method of the Crop-Reporting Board, the ratio $C/\bar{C}_5$ is the probable ratio that the yield per acre of any given year should bear to the mean yield of the preceding five years. But the column marked $Y/\bar{Y}_5$ gives the ratio of the actual yield per acre to the mean yield for the preceding five years. An inspection of the table shows that the two series—the predicted series and the actual series—are not equal. Is

---

[1] *Crop Reporter*, July, 1911, pp. 53-55.

TABLE I

THE ACTUAL YIELD PER ACRE OF OATS IN NORTH DAKOTA COMPARED WITH THE YIELD AS FORECAST FROM THE AUGUST CONDITION OF THE CROP

Year	Condition of the crop August 1 C	Mean condition on August 1 for the preceding 5 years $\overline{C}_5$	$C/\overline{C}_5$	Yield per acre of oats in bushels Y	Mean yield per acre of oats for the preceding 5 years $\overline{Y}_5$	$Y/\overline{Y}_5$
1892 . . .	91	. . . . . .	. . .	26.5	. . . . .	. . .
1893 . . .	75	. . . . . .	. . .	21.9	. . . . .	. . .
1894 . . .	70	. . . . .	. . .	25.9	. . . . .	. . .
1895 . . .	94	. . . . . .	. . .	32.1	. . . . .	. . .
1896 . . .	81	. . . .	. . .	22.0	. . . . .	.
1897 . . .	86	82	105	23.0	25.7	89
1898 . . .	92	81	114	30.7	25.0	123
1899 . . .	88	85	104	30.0	26.7	112
1900 . . .	27	88	31	10.3	27.6	37
1901 . . .	96	75	128	32.6	23.2	141
1902 . . .	95	78	122	38.4	25.3	152
1903 . . .	64	80	80	27.4	28 4	96
1904 . . .	94	74	127	37.4	27.7	135
1905 . . .	95	75	127	38.9	29.2	133
1906 . . .	93	89	104	32.5	35.0	93
1907 . . .	75	88	85	24.5	34.9	70
1908 . . .	73	84	87	23.4	32.1	73
1909 . . .	92	86	107	32.0	31.3	102
1910 . . .	27	86	31	7.0	30.3	23
1911 . . .	58	72	81	23.5	23.9	98
1912 . . .	94	65	145	41.4	22.1	187
1913 . . .	71	69	103	25.7	25.5	101
1914 . . .	84	68	124	28.0	25.9	108
1915 . . .	95	67	142	40.0	25.1	159
1916 . .	77	80	96	21.5	31.7	68
1917 .	52	84	62	15.0	31.3	48
1918 . .	71	76	93	23.5	26.0	90

there any relation between the two series, and if so, how closely are they related, and what is the error made in using the condition-series to forecast the yield-series?

The theory of statistical correlation enables us to answer these questions. Suppose we let the values in the $Y/\overline{Y}_5$ series be represented by y and the values in the $C/\overline{C}_5$ series be represented by x. Then, we know from the theory of correlation, if the association between the variables is linear the closeness of their relation is measured by the coefficient of correlation r, and the straight line connecting the values of y with the values of x is described by the equation

$$(y-\bar{y}) = r\frac{\sigma_y}{\sigma_x}(x-\bar{x})$$

where $\bar{y}$, $\bar{x}$, and σ_y, σ_x are the means and the standard deviations, respectively, of the y's and x's. By putting the reasoning into symbolic form we see the implied assumptions in the method of the Crop-Reporting Board. The method assumes that $y=x$ and, consequently, it implicitly assumes (1) that $r\frac{\sigma_y}{\sigma_x}=1$, and (2) that $\bar{y}=\bar{x}$.

The graph in Figure 1 shows the scatter diagram connecting the yield-series with the condition-series. The equation to the straight line connecting the two series, which is given in Figure 1, was computed from $(y-\bar{y})=r\frac{\sigma_y}{\sigma_x}(x-\bar{x})$. For any given value of x, we may find the corresponding most probable value of y, either by substituting for x in the equation to the straight line and then solving for y, or, by using the graph of Figure 1, obtain the ordinate of the straight line corresponding to the given abscissa. Furthermore, we are able to measure the scatter of the observations about the straight line from the formula $S=\sigma_y\sqrt{1-r^2}$. In the particular case before us $\sigma_y=39.29$; $r=.921$; and, consequently, $S=15.32$. In brief, we know the closeness of the relation between the two series from the value of $r=.921$; we know the law connecting the two series from the equation $y=1.21\,x-19.5$; and we know the magnitude of the error made in using this law as a formula to predict the probable yield per acre, because $S=\sigma_y\sqrt{1-r^2}=15.32$.

If we examine the degree of accuracy of the forecasts obtained by using the method of the Crop-Reporting Board, we shall find that, for this month of August, the results agree very closely with the values of S which we have obtained by the method of correlation. The forecast series in Table I is given in the column marked C/C_5, and the actual series is given in the column marked Y/Y_5. If we take the sum of the squares of the differences between $Y/\bar{Y}_5$ and C/C_5, and divide by the number of cases, we shall have the mean square of the deviations of the actual series from the theoretical series, and this value is comparable with S^2. If we put S' equal to the square root of the mean square of the deviations of the actual series from the predicted series, we may write

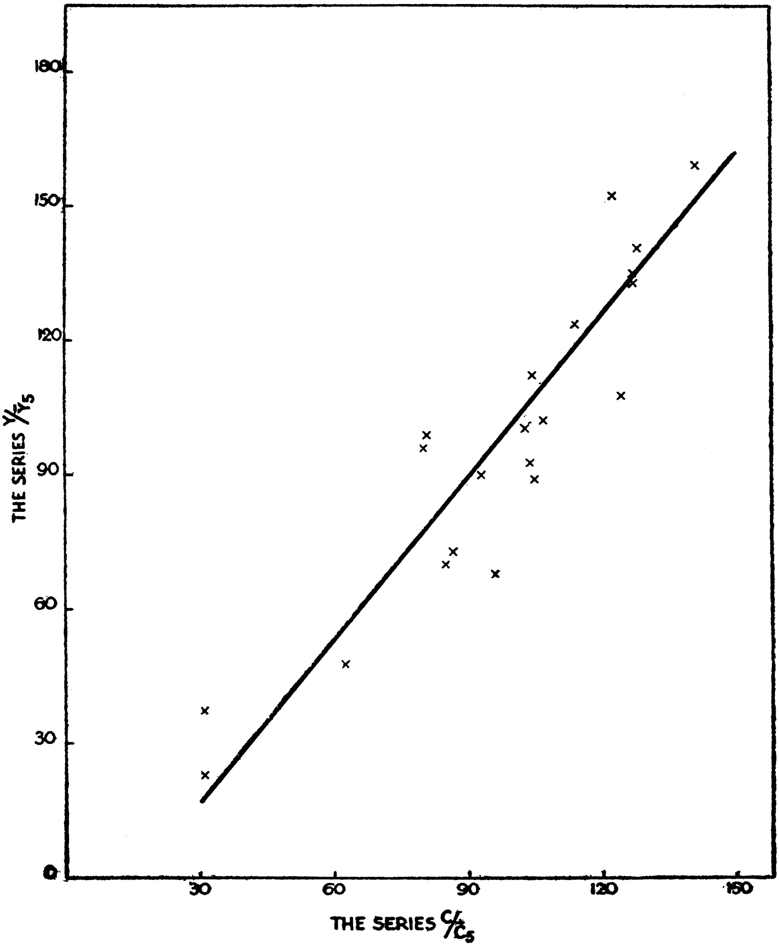

FIGURE 1. Correlation of the actual yield-ratios of oats with the forecasts from the August condition of the crop.

Equation to the straight line, $y = 1.21x - 19.5$, where $y =$ the probable value of $Y/\bar{Y}_5$ and $x = C/\bar{C}_5$.

$$S' = \sqrt{\left\{\frac{\Sigma(Y/\bar{Y}_5 - C/\bar{C}_5)^2}{N}\right\}}$$

where N is the number of years through which the series extends, and $\Sigma(Y/\bar{Y}_5 - C/\bar{C}_5)^2$ indicates the sum of the squares of the deviations, during the several years, of the actual series from the predicted series. The value of S' for August is, $S' = 16.63$. We see, accordingly, that for this month of August, the accuracy of the forecast by the method of the Crop-Reporting Board is almost as great as the accuracy of the method of correlation.

TABLE II

Relative Accuracy of Crop-Yield Forecasting Formulae

(1) The Correlation Equation $(y-\bar{y}) = r\frac{\sigma_y}{\sigma_x}(x-\bar{x})$; $S=\sigma_y\sqrt{1-r^2}$.

(2) The Official Formula $C/\bar{C}_5 = Y/\bar{Y}_5$; $S' = \sqrt{\left\{\frac{\Sigma(Y/\bar{Y}_5 - C/\bar{C}_5)^2}{N}\right\}}$.

Crops	Standard Deviation of the Yield-Ratio σ_y	June			July			August		
		r	S	S′	r	S	S′	r	S	S′
Wheat. . . .	37.36	.614	29.48	34.09	.656	28.21	28.35	.868	18.57	19.00
Oats.	39.29	.645	30.02	36.56	.765	25.30	26.35	.921	15.32	16.63
Barley. . . .	38.12	.642	29.20	34.98	.766	24.51	25.75	.911	15.70	17.10

Now that we have a means for testing the accuracy of the official method of forecasting, we may consider whether the official formula enables one to obtain from the laboriously collected data referring to crop conditions the maximum of information as to the prospective yield. Table II gives the results of the relevant computations,[1] and from this we see that for all three crops, for all of the months in which the reports are tested, the correlation equation gives a more accurate forecast than the official formula.[1]

---

[1] The raw data relating to the "condition of the crops," which are given in the APPENDIX, Table A, were very kindly supplied to me from the governmental records by Mr. Leon M. Estabrook, Chief of the Bureau of Crop Estimates. The figures descriptive of the yield per acre of the three crops, which are given in the APPENDIX, Table B, were compiled from Bulletins 57, 58, 59 of the Bureau of Statistics of the Department of Agriculture, and from the *Yearbooks* of the Department of Agriculture.

Forecasting the Crops from the Weather

In the essay on *Forecasting the Yield and the Price of Cotton* proofs were submitted that it is possible to forecast the yield of cotton more accurately from the accumulated rainfall and temperature in the states of the Cotton Belt than the official experts succeed in achieving from direct observations of the growing crop. Also, a statement was made "that the principles and methods of forecasting the yield of cotton may be utilized in forecasting the yield of other agricultural crops" (page 94). The truth of this statement will now be illustrated by showing how the forecasts, from the weather, of the yield of wheat, oats, and barley in North Dakota are more accurate than the official reports.

In the preparation of the raw data of rainfall, temperature and yield, the example of the Crop-Reporting Board was followed in converting the absolute figures into ratios. Just as the series with which the forecasts of the yield were made from the observed condition of the crops took the form $C/\overline{C}_5$, $Y/\overline{Y}_5$, so, in forecasting the yield from the rainfall and temperature, our raw figures were converted into the ratios $R/\overline{R}_5$, $T/\overline{T}_5$, $Y/\overline{Y}_5$, where R referred to rainfall, T, to temperature, and Y to yield per acre. After the data[2] were converted into series, the next question was to devise forecasting formulae. These formulae were in all cases correlation equations, which differed in form according to the number of variables to be correlated.[3]

When two variables were correlated the essential steps were

(1) The assumption that the two variables were related in a linear way by the equation $y = mx + b$;

(2) The calculation of the coefficient of correlation r;

---

[1] The reasons for the greater accuracy of the correlation formula are discussed in Forecasting the Yield and the Price of Cotton, pp. 69, 78–80.

[2] The crude weather data are given in the APPENDIX, Table C.

[3] The mathematical treatment of the problem is given in Forecasting the Yield and the Price of Cotton, chap. ii and pp. 105–111.

(3) The determination of the accuracy of the equation $y = mx + b$ as a forecasting formula by calculating the scatter $S'' = \sigma_y \sqrt{1 - r^2}$.

When three variables were correlated the essential steps were

(1) The assumption that the equation connecting the three variables x_0, x_1, x_2 was $x_0 = a_0 + a_1 x_1 + a_2 x_2$;

(2) The determination of the degree of association between the variable x_0 and the other two variables x_1, x_2 by calculating the coefficient of multiple correlation R;

(3) The determination of the accuracy of the equation $x_0 = a_0 + a_1 x_1 + a_2 x_2$ as a forecasting formula by calculating the scatter $S'' = \sigma_0 \sqrt{1 - R^2}$.

Table III gives the degree of accuracy of the forecasts by the official method from the direct observations of the growing crops, and the accuracy of the method of correlation from the accumulated effects of the weather.

We see from the table (1) that in eight out of nine cases the forecasts from the weather are more accurate than the official forecasts from the condition of the crops; (2) that the advantage of the forecasts from the weather is greater for the early months than for the later months, or, in other words, the margin between the two forecasts is narrowed with the approach to the harvest; (3) that in the one case in which the forecast by the official method is better than the forecast from the weather the official report is made only about two weeks before the crop is harvested.

The Rainfall and the Crops of the Dakotas

The solution of the problem of forecasting the crops from the changes of the weather very naturally leads one to ask whether the climatic vicissitudes are not themselves subject to law.

In carrying out the computations referring to the influence of the accumulated changes of weather upon the yield of the crops in North Dakota, it became evident that, in case of all three of the crops—wheat, oats and barley—the rainfall of May and June is of critical importance.[1] The correlation be-

---

[1] This importance has been observed in Bulletin No. 757 of the United States Department of Agriculture, *Farm Practices in Grain Farming in North Dakota*, by C. M. Hennis and Rex E. Willard.

TABLE III

RELATIVE ACCURACY IN FORECASTS OF CROP-YIELDS IN NORTH DAKOTA

(1) From the Condition of the Crops by the Official Method. Error = S′.

(2) From the Weather Reports, by the Method of Multiple Correlation. Error = S″.

Crops	Standard Deviation of the Yield-Ratio σ_y	June		July		August	
		S′	S″	S′	S″	S′	S″
Wheat. . . .	37.36	34.09	29.03	28.35	26.08	19.00	20.40
Oats.	39.29	36.56	32.37	26.35	23.34	16.63	15.48
Barley. . . .	38.12	34.98	33.24	25.75	24.97	17.10	15.78

The method of computing S′ has been explained in the discussion referring to Table II.

In obtaining S″ the formulas $S''=\sigma_0\sqrt{1-r^2}$, $S''=\sigma_0\sqrt{1-R^2}$ were used according as one or more independent variables were employed. The combinations of variables were:

In the case of wheat: For June, rainfall-ratio for April and May ($r=.629$); for July, May rainfall-ratio ($r=.621$), June temperature-ratio ($r=-.499$); for August, rainfall-ratio for April, May, June, July ($r=.732$), and temperature-ratio for June and July ($r=-.762$).

In the case of oats: For June, May rainfall-ratio ($r=.566$); for July, rainfall-ratio for May and June ($r=.789$), temperature-ratio for June ($r=-.545$); for August, rainfall-ratio for April, May, June, July ($r=.836$), temperature-ratio for June and July ($r=-.803$).

In the case of barley: For June, May rainfall-ratio ($r=.490$); for July, rainfall-ratio for May and June ($r=.730$), temperature-ratio for June ($r=-.545$); for August, rainfall-ratio for April, May, June, July ($r=.796$), temperature-ratio for June and July ($r=-.827$).

tween the rainfall-ratio for May and June in North Dakota and the yield-ratio of wheat is $r=.66$; of oats, $r=.79$; of barley, $r=.73$. This fact suggested that it would be wise to begin the quest for periodicities in the weather by scrutinizing the data of precipitation for May and June. In order to widen the inquiry, the mean monthly rainfall for May and June in the two Dakotas, from 1882 to 1918, was made the basis of the investigation. The data for North Dakota from 1892 to 1918 and for South Dakota from 1891 to 1918 were taken from the publication of the Weather Bureau *Climatological Data* for 1918.

The precipitation data for the earlier years were compiled from Bulletin W, *Summaries of Climatological Data by Sections*, published by the Weather Bureau, and the records of the following stations were used: Devils Lake, Moorhead (Minn.), Pembina, Bismark, Fort Yates, Williston, Yankton, Huron, Fort Meade and Fort Sully. The figures are given in Table D of the APPENDIX.

When the figures are analyzed by the method of the periodogram to discover whether there are cycles in the May and June precipitation in the Dakotas, one finds from the periodograph, which is given in Figure 2, that if there are cycles in the rainfall during the critical period of the leading crops in the Dakotas the most probable cycles are, approximately, of eight and eleven years in length. If the eight-year cycle is plotted by itself, it will show a maximum at, approximately, 1882, 1890, 1898, 1906, 1914. If the eleven-year cycle is plotted alone it will show a maximum at, approximately, 1882, 1893, 1904, 1915 (see Figure 3). If the two cycles are combined into

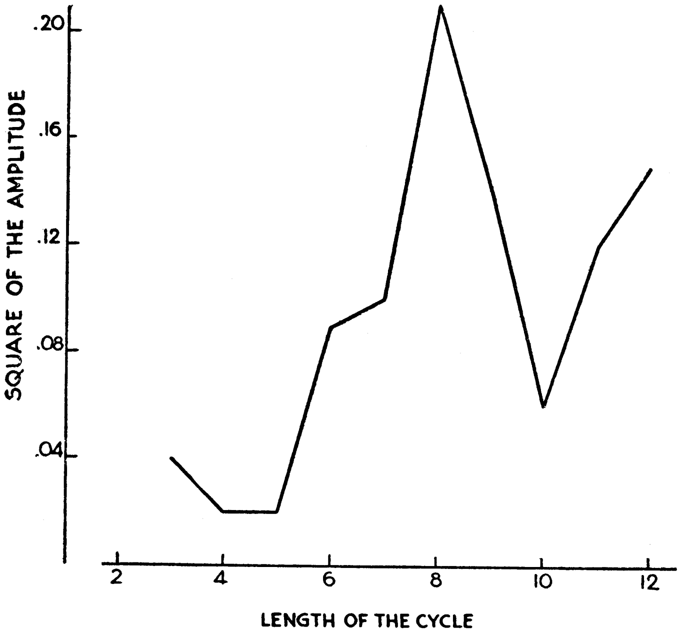

FIGURE 2. The periodogram of May and June rainfall in the Dakotas.

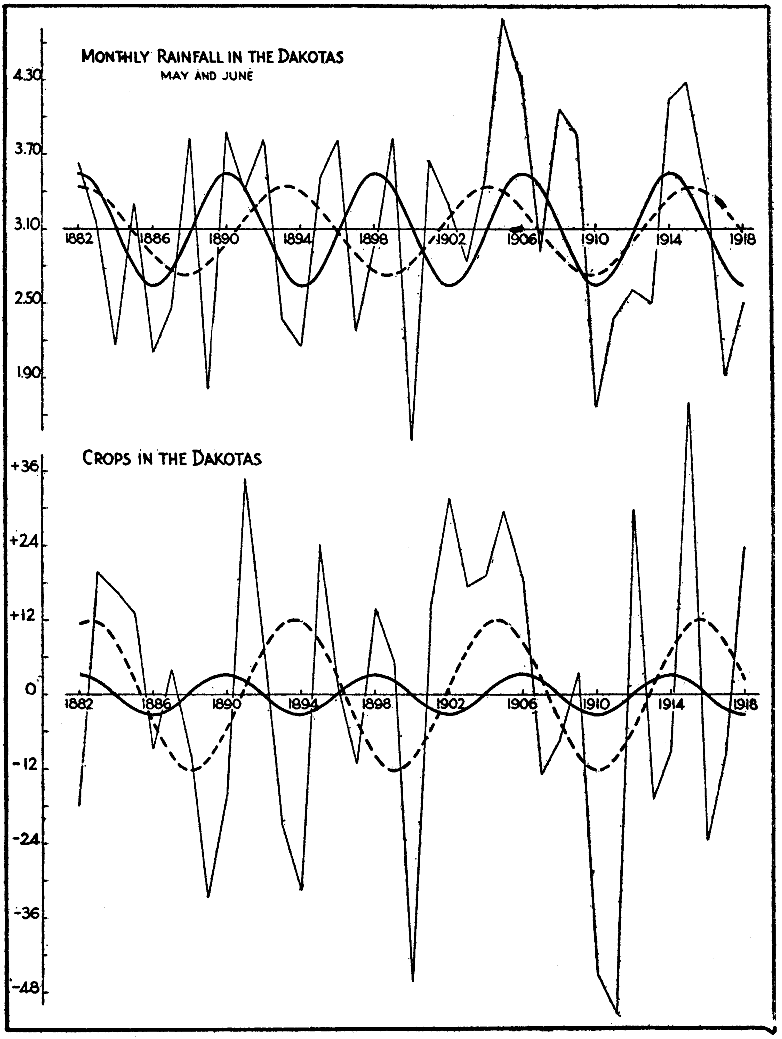

FIGURE 3. Cycles in the rainfall (May and June) and in the crop yield (wheat, oats, and barley) of the Dakotas.

Rainfall cycles: Eight-year cycle (——), $y = 3.09 + .45 \sin \left[\frac{2\pi}{8}t + 84^\circ\, 39'\right]$, origin at 1882;

Rainfall cycles: Eleven-year cycle (- - -), $y = 3.09 + .35 \sin \left[\frac{2\pi}{11}t + 82^\circ\, 25'\right]$, origin at 1882;

Crop cycles: Eight-year cycle (——), $y = .02 + 3.20 \sin \left[\frac{2\pi}{8}t + 93^\circ\, 59'\right]$, origin at 1882;

Crop cycles: Eleven-year cycle (- - -), $y = .02 + 12.17 \sin \left[\frac{2\pi}{11}t + 70^\circ\, 41\right]$, origin at 1882.

a compound cycle of eight years and eleven years, the maxima of the compound cycle will still be approximately at 1882, 1890, 1898, 1906, 1914 (see Figure 4).

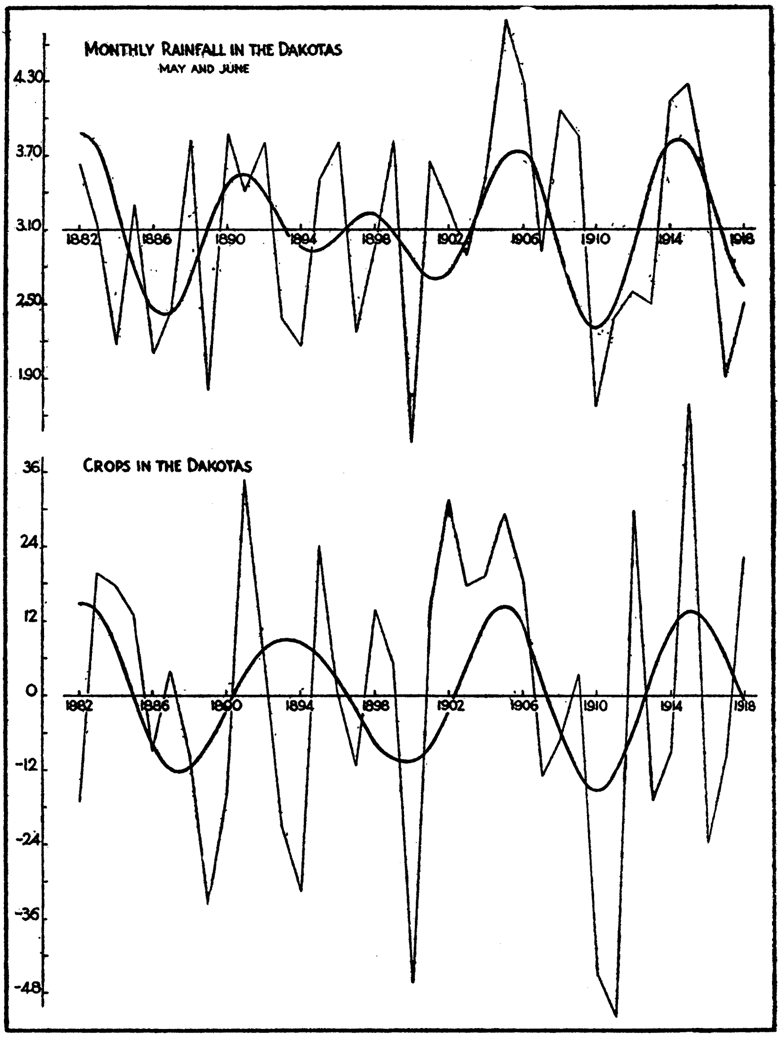

FIGURE 4. The monthly rainfall (May and June) and the crop yield (wheat, oats, and barley) in the Dakotas.

The rainfall curve: $y=3.09 + .45 \sin\left[\frac{2\pi}{8}t + 84^\circ 39'\right] + .35 \sin\left[\frac{2\pi}{11}t + 82^\circ 25'\right]$, origin at 1882;

The crop-yield curve: $y=.02 + 3.20 \sin\left[\frac{2\pi}{8}t + 93^\circ 59'\right] + 12.17 \sin\left[\frac{2\pi}{11}t + 70^\circ 41'\right]$, origin at 1882.

Before leaving this attempt to discover periodicities in rainfall from the records made by the stations of the Weather Bureau, it would be well to observe why one must speak only of approximate results. Apart from the shortness of the records with which one generally has to deal in meteorology and economics, there are two reasons of importance: the first is that when the data are affected with error it is impossible, in using Fourier's theorem to ascertain the length of the period, to give the precise length of the cycle; the second is that, even in meteorology and much more frequently in economics, the methods of making the records are changed in the interval during which the observations run. The argument which we are about to enter upon is not dependent upon the numerical accuracy of any one result, but it derives its force from the convergence of many lines of investigation upon the same conclusion.

We have just seen that there are well-defined cycles of eight and eleven years in the rainfall of the critical period of the crops in the Dakotas. Do the crops pass through similar cycles? To go forward with the investigation an index number of the yield of the crops in the Dakotas, from 1882 to 1918, was constructed in the following manner: The crude data of yield per acre of the three crops were obtained from Bulletins 57, 58, 59 of the Bureau of Statistics of the United States Department of Agriculture and from the *Yearbooks* of the Department of Agriculture. In case of each crop an index number was constructed by taking the mean yield for the ten years 1890–1899 as equal to 100 and expressing the yield for each year of the series as a percentage of the mean yield. Each series of index numbers was found to have a secular trend. To ascertain and eliminate the secular trend, a parabola of the type $y = a + bx + cx^2 + dx^3$ was fitted to the series. The equations to the parabolas were, with the origin at 1900, in the case of wheat, $y = 94.8 + .336x + .0543x^2 - .00344x^3$; in the case of oats, $y = 106.5 + 1.454x + .0560x^2 - .00758x^3$; in the case of barley, $y = 102.4 + .578x + .0118x^2 - .00169x^3$. After the equations to the secular trends of the three crops were derived, the deviations of the actual yield per acre from the secular trends were computed, and these deviations for the three crops were averaged by summing for the several years and then dividing by three. The results formed the index numbers of the deviations of the yield per acre of the three crops. That this index of crop-yield is related to the rainfall of May and June is shown by the coefficient of correlation, which is $r = .52$; and that the general run of the index is due to similar variations of the three crops is shown by the correlation between the deviations of the three crops from their respective trends. The correlation between the deviations of wheat and oats is $r = .74$; between wheat and barley, $r = .78$; and between oats and barley, $r = .91$.

If a cycle of eight years is fitted to this index number of the yield of the three crops, it is found that the curve presents maxima, approximately, at 1882, 1890, 1898, 1906, 1914, and synchronizes with the eight-year cycle in the rainfall of May and June (see Figure 3). If a cycle of eleven years is fitted to the index of the yield, the eleven-year cycle synchronizes with the eleven-year cycle in the rainfall of May and June. This agreement between the constituent cycles of the rainfall curve and the constituent cycles of the crop-yield index might lead one to suppose that the compound cycles would show a perfect accordance. This however is not the case because of the differences in the amplitudes of the constituent cycles. In case of the rainfall curve the eight-year cycle has the greater amplitude and, consequently, when the eight and eleven-year cycles are combined, the eight-year features prevail (see Figure 4). The reverse is the case with the crop index, where the eleven-year cycle has the greater amplitude and determines the characteristic features of the compound crop cycle. The two compound cycles—of rainfall and of crops—show a general resemblance in shape with a notable difference between 1890 and 1898. Notwithstanding this difference the minima of the compound cycle of rainfall are approximately at the times of partial crop failures (see Figure 4).

Crop Cycles in the United States

The Dakotas form the central and most important region in the production of spring wheat, and they make large contributions to the total production of spring oats and spring barley. As the growth season of these crops is limited to the four months of May, June, July and August, one would seem to be justified in believing that the regular cyclical changes in the crop yield of the Dakotas would not be reproduced in other parts of the country where, for example, winter wheat, winter oats and winter barley are cultivated. The belief would seem to be all the more warranted in view of the proof which has just been given that the cycles in the crops of the Dakotas are largely due to the cycles in the rainfall of May and June. Despite these *a priori* objections the investigation was carried out.

In exactly the same way in which an index number was computed for the yield of wheat, oats and barley in the Dakotas, an index was constructed for the yield per acre of these three crops, from 1882 to 1918, in the whole of the United States. The mean yield of each crop from 1890 to 1899 was taken as the base, being represented by 100, and the yield for each year from 1882 to 1918 was expressed as a percentage of this mean. The secular trends in the three series were ascertained by fitting to each a parabola of the third order, the equation to which, with the origin at 1899, was

in the case of wheat, $y=102.1+.952x-.0004x^2-.001101x^3$;

in the case of oats, $y=105.7+.805x+.0258x^2-.00004x^3$;

in the case of barley, $y=103.8+.908x-.0067x^2-.001599x^3$.

The deviations from the secular trend for each crop were computed, and an average of the deviations of the three crops was obtained by summing the deviations for each year and dividing by three.

After the index numbers of the yield of the three crops were derived the correlation between the index for the Dakotas and the index for the United States was computed[1] and found to be $r=.78$. The data were then scrutinized to ascertain whether there were cycles between three and twelve years in length in the yield of the three crops in the United States. The results of the computations are displayed in Figure 5. It is clear from the periodograph that if there are cycles in the yield of wheat, oats and barley in the United States, the lengths of the cycles are in the neighborhood of three, eight and eleven years. We shall reserve comment upon the cycle of approximately three years until further on, and shall examine the cycles in the neighborhood of eight and eleven years.

---

[1] The data are given in APPENDIX, Table D.

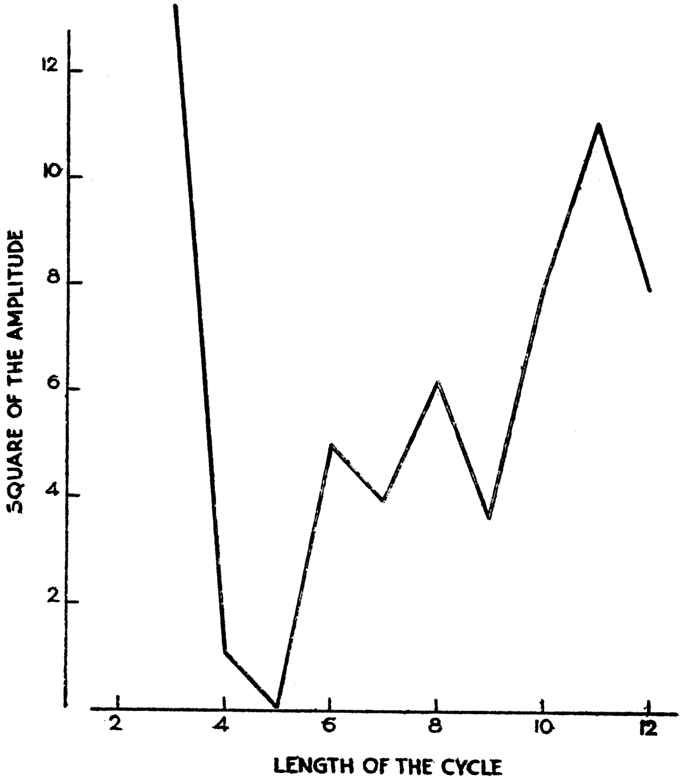

FIGURE 5. The periodogram of the yield of wheat, oats, and barley in the United States.

If the eight-year cycle is computed by itself (see Figure 6) it is found to show maxima at, approximately, 1882, 1890, 1898, 1906, 1914—which are the dates of the maxima indicated by the eight-year rainfall curve in the Dakotas and the eight-year crop cycle in the Dakotas. All three of these curves are congruent. If the eleven-year cycle is computed by itself,

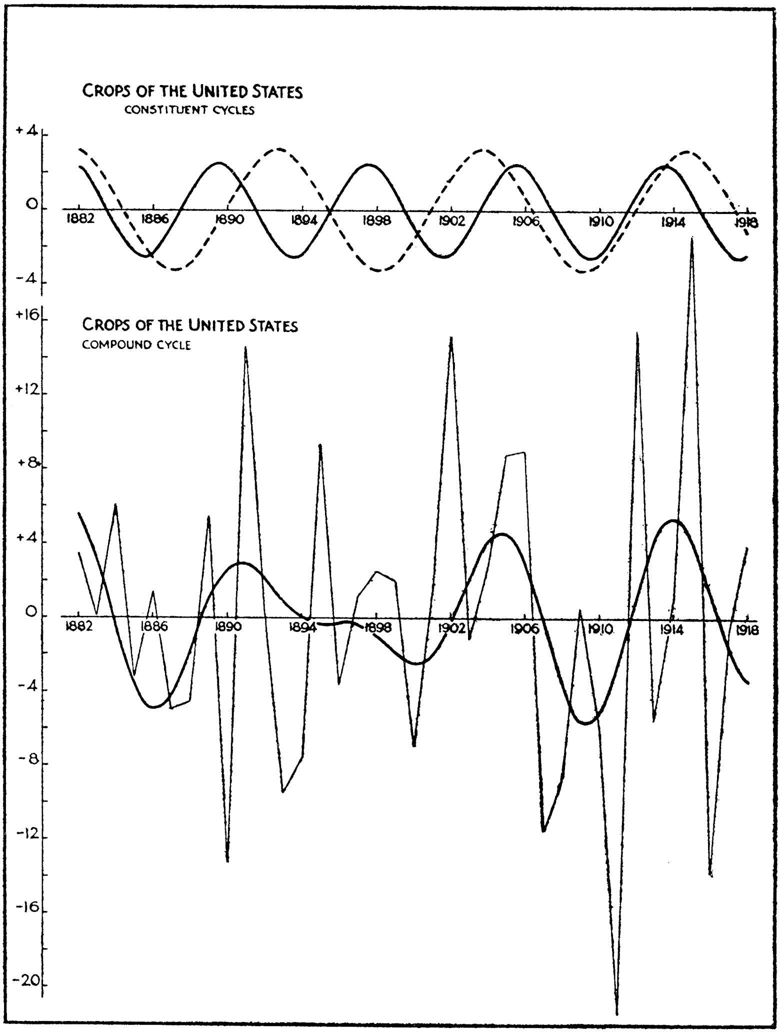

FIGURE 6. Cycles in the yield of wheat, oats, and barley in the United States.

Constituent cycles: Eight-year cycle (——), $y = .10 + 2.49 \sin \left[\frac{2\pi}{8}t + 111^\circ\, 27'\right]$, origin 1882;

Constituent cycles: Eleven-year cycle (- - -), $y = .02 + 3.30 \sin \left[\frac{2\pi}{11}t + 102^\circ\, 8'\right]$, origin 1882;

Compound cycle: $y = .06 + 2.49 \sin \left[\frac{2\pi}{8}t + 111^\circ\, 27'\right] + 3\cdot 30 \sin \left[\frac{2\pi}{11}t + 102^\circ\, 8'\right]$, origin 1882.

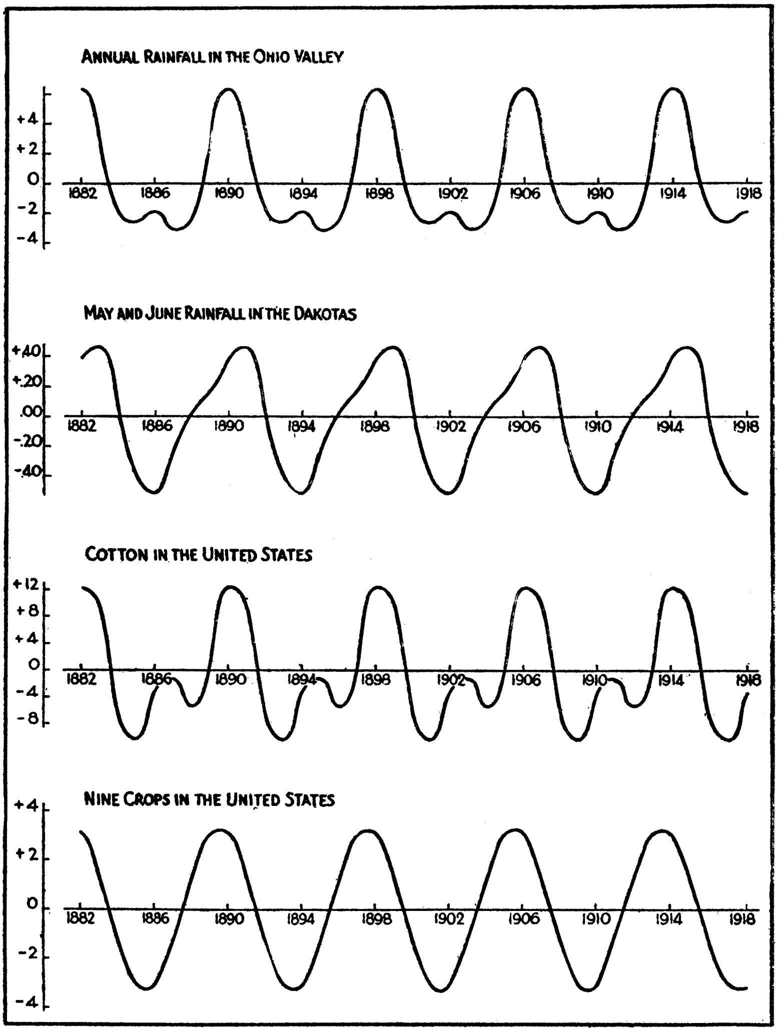

FIGURE 7. Rainfall Cycles and Crop Cycles.

Rainfall of the Ohio Valley:

$$y = 4.13 \sin\left[\frac{2\pi}{8}t + 310^\circ\ 41'\right] + 2.14 \sin\left[\frac{4\pi}{8}t + 180^\circ\ 28'\right], \text{ origin at 1839;}$$

May and June rainfall in the Dakotas:

$$y = .45 \sin\left[\frac{2\pi}{8}t + 84^\circ\ 39'\right] + .14 \sin\left[\frac{4\pi}{8}t + 328^\circ\ 20'\right], \text{ origin at 1882;}$$

Yield of cotton in the United States:

$$y = 7.70 \sin\left[\frac{2\pi}{8}t + 44^\circ\ 25'\right] + 6.67 \sin\left[\frac{4\pi}{8}t + 316^\circ\ 4'\right], \text{ origin at 1881;}$$

Yield of nine crops in the United States:

$$y = 3.36 \sin\left[\frac{2\pi}{8}t + 198^\circ\ 52'\right], \text{ origin at 1884.}$$

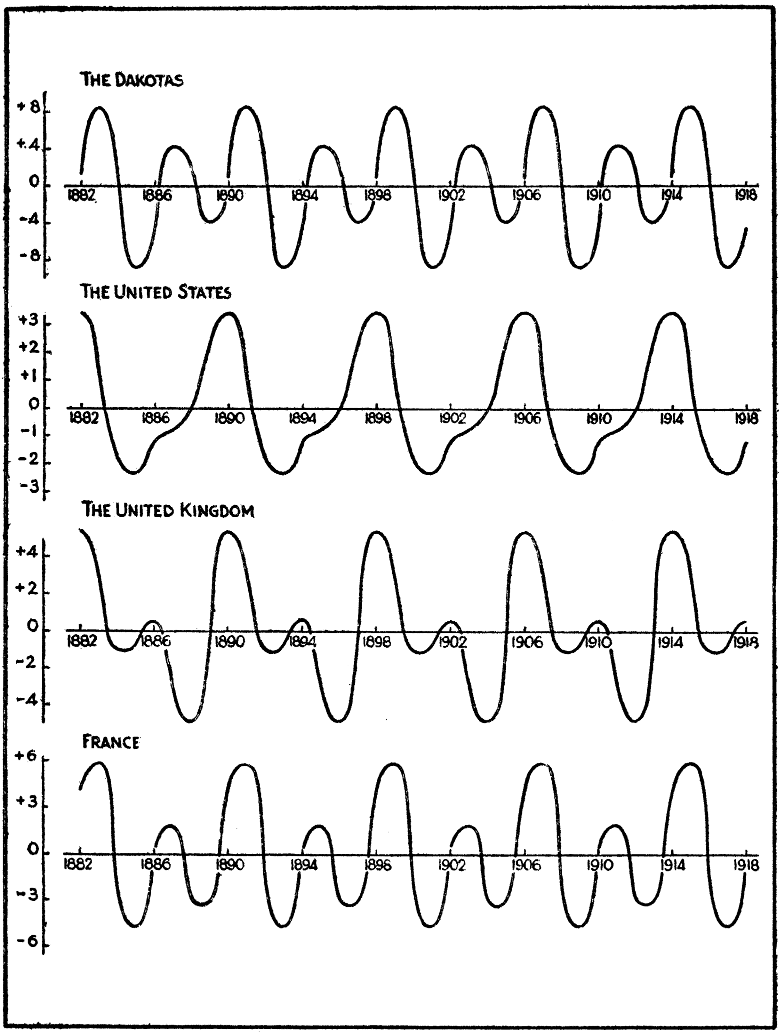

FIGURE 8. Cycles in the yield of wheat, oats, and barley in the Dakotas, the United States, the United Kingdom, and France.

The Dakotas:

$$y = 3.20 \sin\left[\frac{2\pi}{8}t + 93^\circ\ 59'\right] + 6.61 \sin\left[\frac{4\pi}{8}t + 343^\circ\ 45'\right], \text{ origin at } 1882;$$

The United States:

$$y = 2.49 \sin\left[\frac{2\pi}{8}t + 111^\circ\ 27'\right] + 1.03 \sin\left[\frac{4\pi}{8}t + 83^\circ\ 3'\right], \text{ origin at } 1882;$$

The United Kingdom:

$$y = 3.02 \sin\left[\frac{2\pi}{8}t + 142^\circ\ 0'\right] + 2.94 \sin\left[\frac{4\pi}{8}t + 261^\circ\ 3'\right], \text{ origin at } 1884;$$

France:

$$y = 2.17 \sin\left[\frac{2\pi}{8}t + 292^\circ\ 56'\right] + 4.40 \sin\left[\frac{4\pi}{8}t + 118^\circ\ 51'\right], \text{ origin at } 1879.$$

it is found to show maxima at, approximately, 1882, 1893, 1904, 1915—which are the approximate dates in the maxima of the eleven-year rainfall cycle in the Dakotas and the eleven-year crop cycle in the Dakotas.[1] If a compound cycle of eight and eleven years is computed and drawn, the compound cycle resembles both the compound rainfall cycle of the Dakotas and the compound crop cycle of the Dakotas (see Figures 3, 4 and 6).

International Comparisons

The periodogram of the yield of wheat, oats and barley in the United States indicated that the most probable crop cycles between three and twelve years in length are in the neighborhood of three, eight and eleven years. The cycles of eight and eleven years we have examined, and before proceeding to international comparisons a word is to be said about the apparent cycle of three years. It is quite possible that the true length of the cycle is nearer three years than four years, but I shall assume, for the purpose of international comparison, that the true length is nearer four than three. Some ground for taking this liberty was suggested a while ago when I pointed out how impossible it is to determine the exact length of cycles when the series of observations are short and affected with error. As our crop-yield statistics are notoriously inexact, it would not be surprising if the maximum ordinates of the periodogram of yield are somewhat dislocated when the yields of the three crops through a relatively short period are combined by mathematical methods into an index number.

Separate and independent studies have previously been made of the most probable cycles between three and twelve years in the rainfall of the Ohio Valley,[2] the yield of cotton in the United States,[3] the yield of wheat, oats and barley in the United Kingdom,[4] the yield of wheat, oats and barley in France.[5]

---

[1] The eleven-year cycles to which reference has just been made are synchronous with the eleven-year period of sunspots. At another time I expect to treat with some detail the relation of solar periodicities and social changes.

[2] Economic Cycles: Their Law and Cause, p. 16.

[3] *Journal of the Royal Statistical Society*, May, 1919.

[4] *Ibid.*, May, 1919

[5] *Ibid.*, May, 1920.

These independent studies indicated (i) that if there are cycles between three and twelve years in the separate series their most probable lengths are in the neighborhood of eight and four years; and (ii) that in all cases the major maxima of the compound cycles of eight and four years occur at about 1882, 1890, 1898, 1906, 1914, with minor maxima midway between these dates. It was also pointed out in an earlier study[1] that the yield of nine crops in the United States shows a cycle of about eight years with maximum ordinates occurring at about 1882, 1890, 1898, 1906, 1914 (see Figures 7 and 8).

Additional results have been reached in this paper. We have computed the periodogram of the May and June rainfall in the Dakotas, and the periodogram of the yield of wheat, oats and barley in the United States. In both cases there is clear evidence of the existence of the eight-year cycle whose maximum ordinates appear in the neighborhood of 1882, 1890, 1898, 1906, 1914. The rainfall of May and June occurs at the critical period in the growth of wheat, oats and barley in the Dakotas, so that a cycle of eight years in length synchronizing with the May and June rainfall appears in the yield of the Dakota crops. If now we compute compound cycles of eight and four years for the May and June rainfall of the Dakotas, the yield of wheat, oats and barley in the Dakotas, and the yield of wheat, oats and barley in the United States, the major maxima in all three cases occur at about 1882, 1890, 1898, 1906, 1914, with the minor maxima about midway between these dates (see Figures 7 and 8).

The findings of the present paper combined with the results of the earlier studies enable us to conclude that the compound cycles of eight and four years in the annual rainfall of the Ohio Valley, the May and June rainfall in the Dakotas, the yield of cotton in the United States, the yield of wheat, oats and barley in the Dakotas, in the United States, in the United Kingdom and in France are, as far as concerns the dates of their maxima and minima, practically synchronous.

HENRY L. MOORE.

COLUMBIA UNIVERSITY.

---

[1] *Journal of the Royal Statistical Society*, May, 1919.

APPENDIX

TABLE A

THE OFFICIAL MONTHLY ESTIMATES OF THE CONDITION OF THE GROWING CROPS IN NORTH DAKOTA

Year	Condition of the Crops								
	Wheat			Oats			Barley		
	June 1	July 1	August 1	June 1	July 1	August 1	June 1	July 1	August 1
1892	92	90	85	90	92	91	89	90	90
1893	92	73	66	94	77	75	96	81	78
1894	97	68	75	100	65	70	102	77	68
1895	99	102	104	90	121	94	84	92	102
1896	103	96	70	92	93	81	95	82	78
1897	91	95	90	88	87	86	92	91	91
1898	104	92	95	100	95	92	100	99	91
1899	93	94	86	94	95	88	95	93	94
1900	79	30	25	82	28	27	79	31	28
1901	91	100	93	91	98	96	90	94	96
1902	96	96	93	96	96	95	98	97	95
1903	99	73	69	97	73	64	99	76	63
1904	94	95	90	93	94	94	94	95	93
1905	95	92	91	94	93	95	94	92	93
1906	95	93	88	95	96	93	94	95	92
1907	90	88	72	89	89	75	90	89	81
1908	97	93	75	98	94	73	96	94	74
1909	98	95	93	96	94	92	96	93	90
1910	93	45	34	90	42	27	88	45	23
1911	95	88	60	95	84	58	95	84	71
1912	96	92	94	96	91	94	94	90	92
1913	91	70	68	92	71	71	92	72	71
1914	94	94	81	93	94	84	92	93	80
1915	94	93	95	94	92	95	93	90	94
1916	86	88	62	89	90	77	87	91	74
1917	86	73	55	85	75	52	83	74	55
1918	93	85	73	92	85	71	93	87	77

TABLE B

Yield Per Acre of the Crops in North Dakota

Year	Yield per Acre in Bushels		
	Wheat	Oats	Barley
1892	12.2	26.5	24.3
1893	9.6	21.9	15.2
1894	11.8	25.9	20.0
1895	21.0	32.1	30.4
1896	11.8	22.0	16.1
1897	10.3	23.0	22.5
1898	14.4	30.7	26.4
1899	12.8	30.0	24.0
1900	4.9	10.3	8.2
1901	13.1	32.6	28.2
1902	15.9	38.4	31.6
1903	12.7	27.4	21.6
1904	11.8	37.4	28.1
1905	14.0	38.9	28.0
1906	13.0	32.5	25.8
1907	10.0	24.5	18.3
1908	11.6	23.4	19.5
1909	13.7	32.0	21.0
1910	5.0	7.0	5.5
1911	8.0	23.5	19.5
1912	18.0	41.4	29.9
1913	10.5	25.7	20.0
1914	11.2	28.0	19.5
1915	18.2	40.0	32.0
1916	5.5	21.5	15.5
1917	8.0	15.0	12.5
1918	13.0	23.5	21.5

TABLE C

THE WEATHER IN NORTH DAKOTA. TEMPERATURE (DEGREES FAHRENHEIT) AND RAINFALL (INCHES)

Years	April		May		June		July	
	Temperature	Rainfall	Temperature	Rainfall	Temperature	Rainfall	Temperature	Rainfall
1892..	37.6	2.65	46.6	2.21	60.5	3.55	68.7	3.23
1893..	34.3	1.73	52.2	1.61	67.4	3.38	69.5	2.04
1894..	42.8	3.06	54.6	1.51	68.8	3.44	71.7	0.53
1895..	49.6	2.23	54.4	2.48	59.7	4.67	66.1	2.90
1896..	40.1	4.37	56.9	4.89	65.6	3.80	67.5	1.59
1897..	40.8	1.01	55.4	0.71	61.7	3.75	68.9	4.43
1898..	41.9	1.38	52.7	1.98	62.6	3.19	67.6	2.49
1899..	38.0	1.36	50.6	3.49	62.2	3.81	68.3	2.34
1900..	49.3	0.75	59.2	0.69	66.9	1.39	67.9	2.25
1901..	44.5	0.98	60.0	0.31	61.6	6.16	70.8	4.28
1902..	40.2	1.06	55.9	3.57	58.0	3.65	67.6	2.15
1903..	42.5	1.23	54.3	3.08	62.4	1.44	66.7	2.23
1904..	37.4	1.70	54.2	1.76	61.4	5.77	64.4	2.49
1905..	40.2	0.63	50.1	3.05	59.7	4.52	65.6	3.90
1906..	46.7	1.50	50.8	4.63	62.0	4.06	66.9	1.97
1907..	31.9	0.57	44.0	1.11	61.9	2.85	65.8	3.14
1908..	43.9	1.47	50.8	2.97	60.4	3.37	68.6	2.10
1909..	34.2	0.81	51.0	4.29	62.9	2.21	67.1	2.89
1910..	48.0	1.30	50.7	0.96	67.3	1.83	70.0	1.60
1911..	41.5	1.30	55.0	2.88	66.9	3.12	65.1	1.82
1912..	44.4	2.34	54.2	4.52	61.8	2.05	66.0	3.54
1913..	46.8	0.71	51.2	1.68	65.8	2.35	65.6	2.30
1914..	40.9	1.66	55.2	2.12	62.2	6.26	72.1	2.31
1915..	50.3	1.08	51.1	3.16	56.7	5.00	62.3	3.01
1916..	39.2	1.40	51.0	2.22	58.0	3.89	73.1	3.16
1917..	37.2	1.68	51.2	0.30	59.7	2.09	70.9	1.66
1918..	41.4	2.15	51.7	2.30	63.3	1.63	65.5	2.71

TABLE D

Data Relating to the Mean Monthly Rainfall in the Dakotas and to the Index Number of the Yield Per Acre of Wheat, Oats, and Barley in the Dakotas and in the United States

Year	Monthly Rainfall in the Dakotas May and June (Inches)	Index Number of Yield per Acre	
		The Dakotas	United States
		Deviations from trend	Deviations from trend
1882	3.63	—18.0	+ 3.5
1883	3.14	+19.8	+ 0.1
1884	2.17	+16.8	+ 6.1
1885	3.30	+13.0	— 3.3
1886	2.11	— 9.0	+ 1.4
1887	2.46	+ 4.0	— 4.9
1888	3.83	— 9.4	— 4.6
1889	1.81	—32.8	+ 5.5
1890	3.88	—16.1	—13.3
1891	3.41	+34.9	+14.7
1892	3.81	+ 6.9	+ 0.3
1893	2.37	—21.2	— 9.5
1894	2.16	—31.6	— 7.6
1895	3.50	+24.1	+ 9.4
1896	3.81	+ 0.4	— 3.7
1897	2.27	—11.3	+ 1.2
1898	2.96	+13.9	+ 2.5
1899	3.83	+ 5.6	+ 2.0
1900	1.39	—46.4	— 7.0
1901	3.66	+14.0	+ 1.5
1902	3.30	+31.6	+15.3
1903	2.89	+17.7	— 1.1
1904	3.51	+19.1	+ 2.8
1905	4.80	+29.4	+ 8.8
1906	4.28	+18.7	+ 9.0
1907	2.92	—12.9	—11.5
1908	4.07	— 7.2	— 8.8
1909	3.86	+ 3.2	+ 0.6
1910	1.67	—45.2	— 5.8
1911	2.38	—51.8	—21.4
1912	2.60	+29.9	+15.6
1913	2.50	—17.1	— 5.5
1914	4.14	— 9.1	+ 1.0
1915	4.28	+46.8	+20.7
1916	3.46	—23.9	—13.7
1917	1.91	— 9.6	— 0.6
1918	2.51	+23.8	+ 4.1